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THE USE OF EXPANDED TEN-MINUTE COUNTS AS ESTIMATES OF HOURLY SALMON MIGRATION PAST COUNTING TOWERS ON ALASKAN RIVERS

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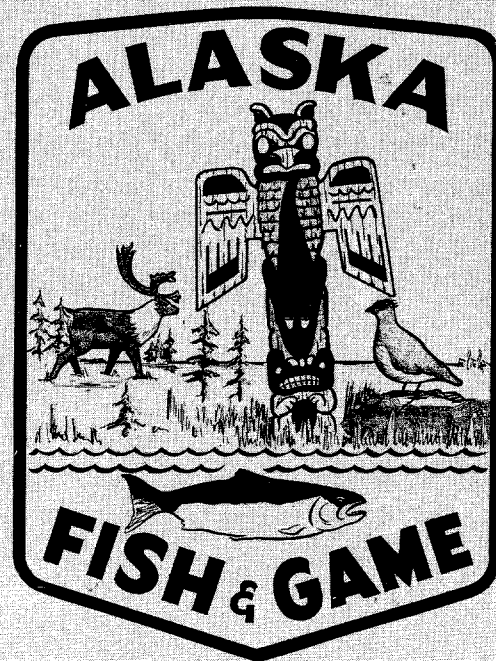
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ABSTRACT

Data collected during the 1965-66 seasons at the counting towers on eight Alaskan rivers was analyzed to evaluate the use of 10-minute counts per hour as the basis for estimating the magnitude of the hourly migration, and hence, the daily and seasonal migration of salmon returning to spawn. In general, relatively large errors between the hourly estimates (based on 10-minute counts) and the hourly counts (assumed to be the hourly migration) could be tolerated if these errors were unbiased and tended to cancel out over the duration of the season.

The relative errors between the sample total hourly estimates and total hourly counts ranged from -34.9% to +21.8%. These errors were equally divided between over-estimates and under-estimates. The arithmetic mean relative error of +0.9% was not statistically different from zero at the 95% level. The 95% confidence interval for the mean relative error was (-7.1%, + 8.9%).

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I. INTRODUCTION

In managing a commercial salmon fishery to obtain maximum sustained yield, one of the most important single pieces of information which must be obtained each year is an estimate (either total or index) of the number of salmon migrating up a river or stream to spawn. This annual estimate of escapement not only represents the number of parent spawners allowed to propagate the species, but, when combined with the annual commercial catch to produce the total annual return, it provides the basis for evaluating the success or efficiency of a given parent spawning population.

The problem of enumerating spawning populations of salmon has been approached in a number of different ways: W.F. Thompson (1962) gives a short review of some of the different methods experimented with in Alaska for enumeration of salmon. These include direct surveys (either aerial or by foot) of the spawning grounds, weirs, mark-recovery, etc. Each method was plagued with disadvantages such as excessive cost, lack of precision, inconsistency in estimates from year to year, etc. In the early 1950's, as a result of observing the phenomena of sockeye (Oncorhynchus nerka) salmon migrating in narrow bands along the banks of clearwater rivers in Bristol Bay, counting towers were set up on the Wood River. Figure I illustrates the type of tower presently being utilized in Bristol Bay. The success of these first towers as a means of enumerating migrating salmon resulted in the expanded use of counting towers. At present, escapements to ten rivers in Bristol Bay (cf. Figure 2) are enumerated through the use of counting towers. Less than five percent of the sockeye spawning in Bristol Bay must be estimated by aerial and/or foot surveys of the spawning grounds. In addition, counting towers have received limited use in other parts of Alaska. Although sockeye are the primary species of salmon enumerated through the use of counting towers, there are several instances where other species have also been successfully enumerated by the same method. In particular, counting towers may be used effectively on small, shallow rivers such as the Kwiniuk River in Norton Sound even though the salmon, primarily

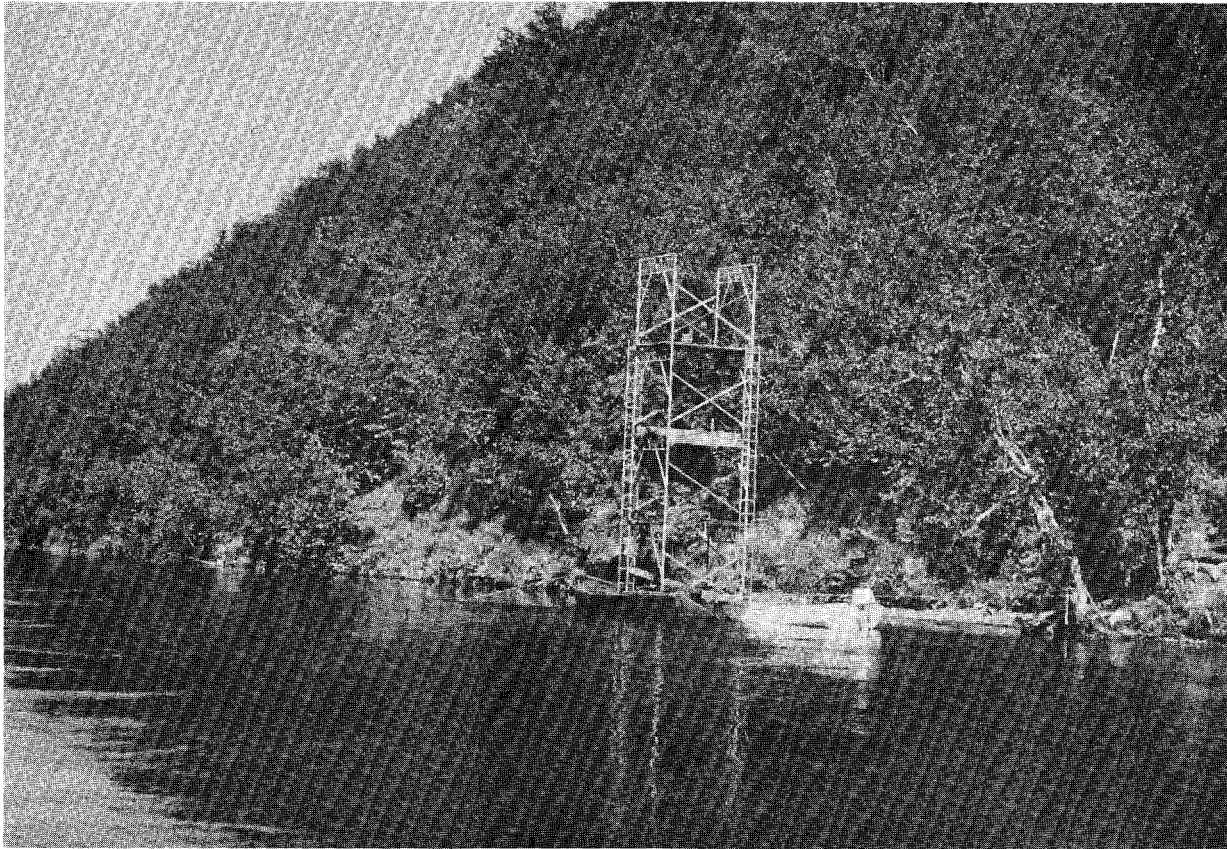


Figure 1. Counting tower presently in use on the Wood River, Bristol Bay, Alaska.

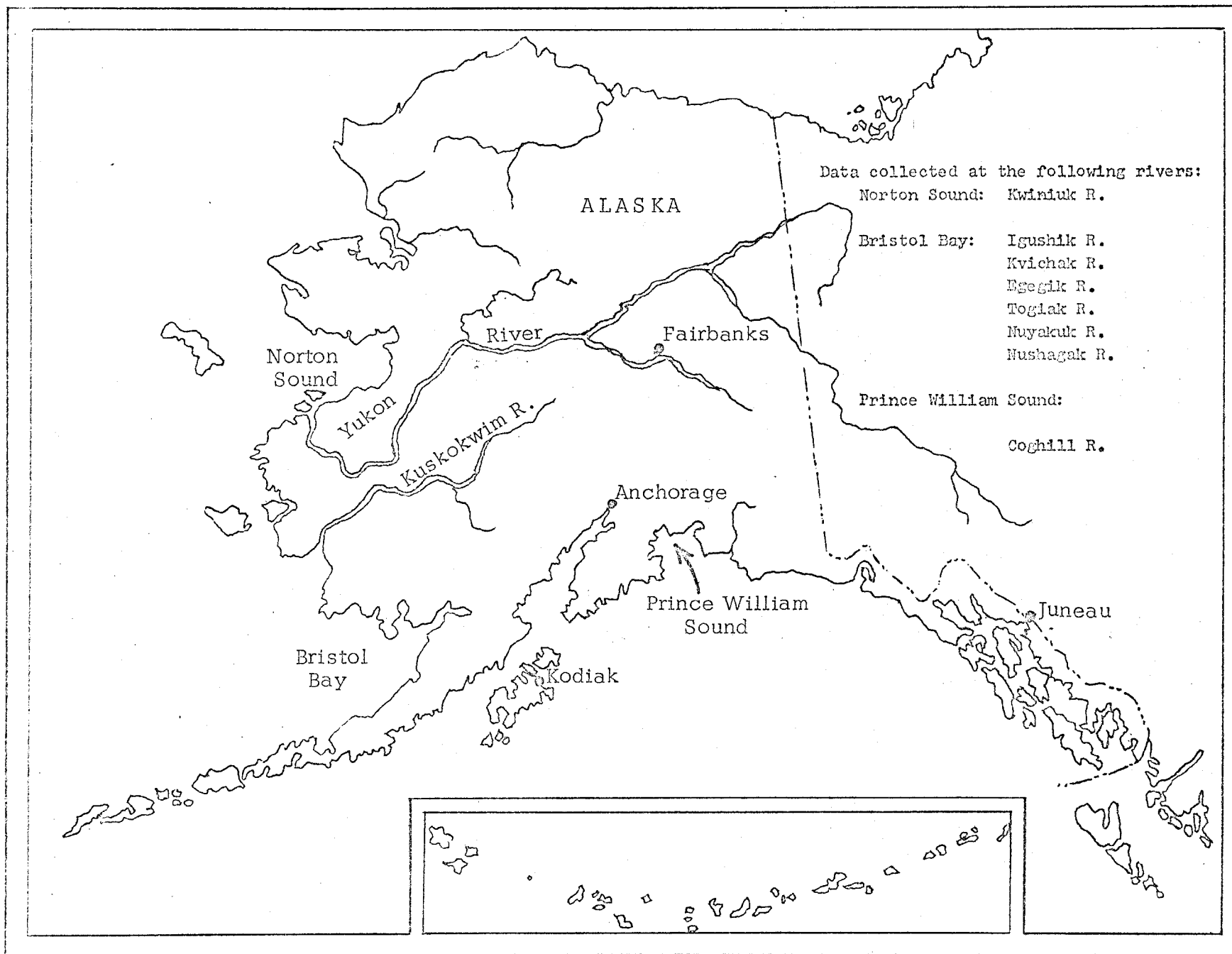


Figure 2. General locations of Alaskan rivers at which counting tower studies were conducted.

chums (O. keta) and pinks (O. gorbuscha), do not migrate in the same "band" pattern exhibited by the sockeye in Bristol Bay. In addition to providing estimates of annual escapements, the counting towers also provide a valuable check on the accuracy of aerial surveys, which are extremely important to the management of the Alaskan salmon fisheries.

Counting towers do not provide error-free estimates of the escapements to the individual rivers. Some errors may be introduced by 1) deviations from the "band" pattern of migration which result in fish failing to pass close enough to the tower to be observed, 2) poor visibility as a result of adverse weather and/or water conditions, and 3) large migration rates which necessitate estimating (by 10's, 100's, etc.) the number of fish passing by the tower. However, in general the degree of accuracy of escapement estimates obtained through the use of counting towers is comparable with the accuracy of other biological data collected and used to describe the population dynamics of the salmon stocks.

Studies were conducted in 1956-57 by the Fish and Wildlife Service (Rietze, 1957, Spangler and Rietze, 1958) to compare the counts obtained by counting towers with those obtained from weirs. On the Egegik River in 1956 an estimated 984,908 fish passed the counting tower as compared with 1,063,877 salmon counted through the weir during the sampling period. This represents a -7.4% relative error in the tower estimate with respect to the weir estimate. In 1957 an estimated 712,124 salmon passed the counting towers while 631,001 were estimated to have passed the weir during the sampling period. This represents a +12.9% relative error in the tower estimate with respect to the weir estimate. These studies indicated that the majority of the salmon travel in the shallow water near the banks of the river (in an effort to escape the main current) and, therefore, can be counted from towers situated on or near the banks with acceptable levels of accuracy.

Due to cost considerations only limited personnel can be placed at the counting towers on each river, and since these personnel are also required to conduct other studies such as sampling adult salmon for age-weight-length data, smolt enumeration, etc., it is desirable to reduce the actual time spent counting fish as much as possible without introducing undesirable errors. On the basis of the early studies by Fisheries Research Institute and the U.S. Fish and Wildlife Service (Becker, 1962, Rietze, 1957), it was decided that counts made 10 minutes out of each hour and expanded appropriately would provide adequate estimates of the hourly migration.

Because of the importance of obtaining accurate estimates of escapement, and since the use of counting towers has been extended to more rivers in Alaska, it was decided to re-evaluate the use of ten-minute counts as the basis for estimating the hourly migrations and, hence, the total annual escapement. Special concern was for those systems with small escapements

which often exhibit very erratic patterns of migration. The development of runs to these smaller systems can help return salmon production in Alaska to the higher levels exhibited in the early years of the fisheries.

II. EXPERIMENT DESIGN AND COLLECTION OF DATA

The primary objective of this study was to evaluate the use of hourly ten-minute counts as the basis for estimating hourly migration, and hence, total seasonal migration. In general, the accuracy of the hourly estimates is of interest only in respect to the effect it has on the accuracy of the seasonal estimates of escapement as obtained from the cumulative sum of the hourly estimates. In other words, a significant amount of relative error could be tolerated for the individual hour counts if these errors tended to cancel out and produce only small relative errors in the total season estimates.

The primary data collected consisted of hour counts obtained by making six consecutive ten-minute counts. The first ten-minute count was then multiplied by six to obtain an estimate of the hourly migration which was to be compared with the total hour count. In the remainder of this report, these two estimates of the hourly migration will be termed "hourly count" and "hourly estimate" to distinguish between the estimate obtained by counting for the entire hour and the estimate obtained by multiplying the ten-minute count by six. For the purpose of this report, the hourly counts will be assumed to be the actual number of salmon migrating past the counting tower during that hour.

In addition to the actual tower counts, weather and water conditions were also recorded. Figure 3 illustrates the form used to record the collected data.

In order that the data collected would be representative of the variable conditions encountered on Alaskan rivers, data was collected during both the 1965 and 1966 seasons from six rivers in Bristol Bay, one in Norton Sound and one in Prince William Sound. The approximate location of these rivers is shown in Figure 2. Thus, the data collected represents tower counts obtained under a wide variety of weather and water conditions, river types and migration rates. In some instances, chum and pink salmon were also counted.

In general, the hourly counts were obtained during the season as time permitted as it was not feasible (or necessary) to make total hour counts for the entire season. However, in 1966 the large number of hourly counts made on the Kwiniuk River necessitated sub sampling these counts to simplify the computations required for analysis. The first 36 counts were chosen with the restriction that only those total hour counts greater than 50 were chosen. This restriction was made to prevent a large number

Figure 3. COUNTING TOWER EFFICIENCY STUDY FORM

FG-1

Alaska Department of Fish and Game

Location _____

Page _____ / _____

DATE			OBSERVER	WEATHER, ETC.		
MO	DAY	YR	INITIALS	SKY	WIND	WATER

TOWER SITE			TIME		SALMON COUNT												TOTAL COUNT						
BANK ₁₃			HR ₁₅	MIN ₁₆	RED ₂₀			CHUM ₂₄			KING ₂₈			COHO ₃₂			PINK ₃₆			COUNT ₄₁			
				1																			
				2																			
				3																			
				4																			
				5																			
				6																			

TOWER SITE			TIME		SALMON COUNT												TOTAL						
BANK			HR	MIN	RED			CHUM			KING			COHO			PINK			COUNT			
				1																			
				2																			
				3																			
				4																			
				5																			
				6																			

TOWER SITE			TIME		SALMON COUNT																								TOTAL			
BANK			HR	MIN	RED				CHUM				KING				COHO				PINK				COUNT							
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TOWER SITE			TIME		SALMON COUNT												TOTAL											
BANK			HR	MIN	RED				CHUM				KING				COHO				PINK				COUNT			
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					6																							

Remarks _____

of very small counts (including zero) from occurring in the sample. Total hour counts were made throughout the 1965 and 1966 seasons on the Kwiniuk River and were used for comparison with escapement estimates based on aerial surveys.

III. BASIC DATA AND RESULTS OF ANALYSIS

The basic data collected in the form of hourly estimates (ten-minute counts multiplied by six) and hourly counts (counts made for the entire hour) is given in Appendix Tables A-1 through A-12. For the Kvichak and Egegik Rivers the data is given separately for the left and right bank towers for the sake of comparison; however, for the other rivers the data for both banks was combined to obtain adequate sample sizes. Counts are given by species except in the case of the Coghill River counts, where conditions did not allow accurate separation by species.

Sample sizes (i.e., number of total hour counts) varied from a minimum of 12 on the Igushik River in 1965 to 80 on the Coghill River in 1965. Total sample counts varied from 1,187 sockeye counted at the Togiak tower in 1966 to 585,700 sockeye counted at the Kvichak left bank tower in 1965. Average hourly migration rates (total fish counted divided by number of hours counted) during the sampling period varied from 24 fish per hour on the Nuyakuk River in 1966 to 17,630 fish per hour on the right bank of the Kvichak River in 1965.

A summary of the data collected for each system is given in Table 1. For the sake of illustration, the data collected from the Egegik River in 1965 is graphed in Figure 4.

Analysis

Regression analysis was applied to the data given in Appendix Tables A-1 through A-12. Analysis of variance tables are given in Appendix Table B-1. To circumvent the assumption of a bivariate normal population, which is necessary if the sample correlation coefficient r is to be used as an unbiased estimate of the population correlation coefficient ρ , the coefficient of determination r^2 was calculated to provide a measure of the linear relationship between the hourly estimates and the hourly counts. The resulting values are given in Table 1. These values vary from a minimum of 0.464 (Kwiniuk River, 1966) to a maximum of 0.986 (Nuyakuk R., pinks, 1966). The geometric mean coefficient of determination $r^2 = 0.733$ indicates that, on the average, approximately 70% of the sum of squared deviations of the hourly estimates is explained by the hourly counts (which were assumed to be the actual migration relative to the hourly estimates).

Table 1. Summary of 1965-66 Counting Tower Data and Analysis

Year	System	Species	Sample Size ^{1/}	Total Sample Count ^{2/}	% of Total Migration Counted ^{3/}	Ave. Hourly Migration Rate ^{4/}	Coeff. of Determination	Coeff. of Variation	Relative Error ^{5/}
1965	Kwiniuk River	Chum	53	6,302	19.4	119	0.630	1.5	+10.6
		Pink	35	1,249	14.4	36*	0.575	1.8	+ 8.6
	Igushik River	Sockeye	12*	2,700	1.5	225	0.676	1.4	-34.9*
	Kvichak River								
		Left Bank	36	585,700*	2.4	16,270	0.872	0.5	- 4.7
		Right Bank	22	387,950	1.6	17,630*	0.707	0.4*	- 3.1
	Egegik River								
		Left Bank	24	24,820	1.7	1,034	0.968	1.7	+13.4
1966	Coghill River	Right Bank	23	43,281	3.0	1,882	0.810	1.3	+ 1.3
		Mixed ^{6/}	80*	14,974	29.6 ^{7/}	187	0.558	0.7	-10.1
	Kwiniuk River	Chum	36	7,295	22.0	203	0.464*	0.9	- 5.3
		Pink	36	5,213	48.0*	145	0.575	0.7	- 0.8
	Togiak River	Sockeye	15	1,187*	1.3	79	0.935	1.5	+21.8*
	Nuyakuk River	Sockeye	24	16,494	10.2	687	0.893	1.7	+ 0.6
		Pink	32	12,361	0.9*	386	0.973*	2.2*	+16.3
	Nushagak River	Pink	14	34,028	(0.9*) ^{7/}	2,430	0.897	1.3	- 1.1

* Indicates maximum and minimum values for each column.

^{1/} Number of total hour counts.

^{2/} Total salmon counted during sample hours.

^{3/} Percent of total season migration counted during the sample hours.

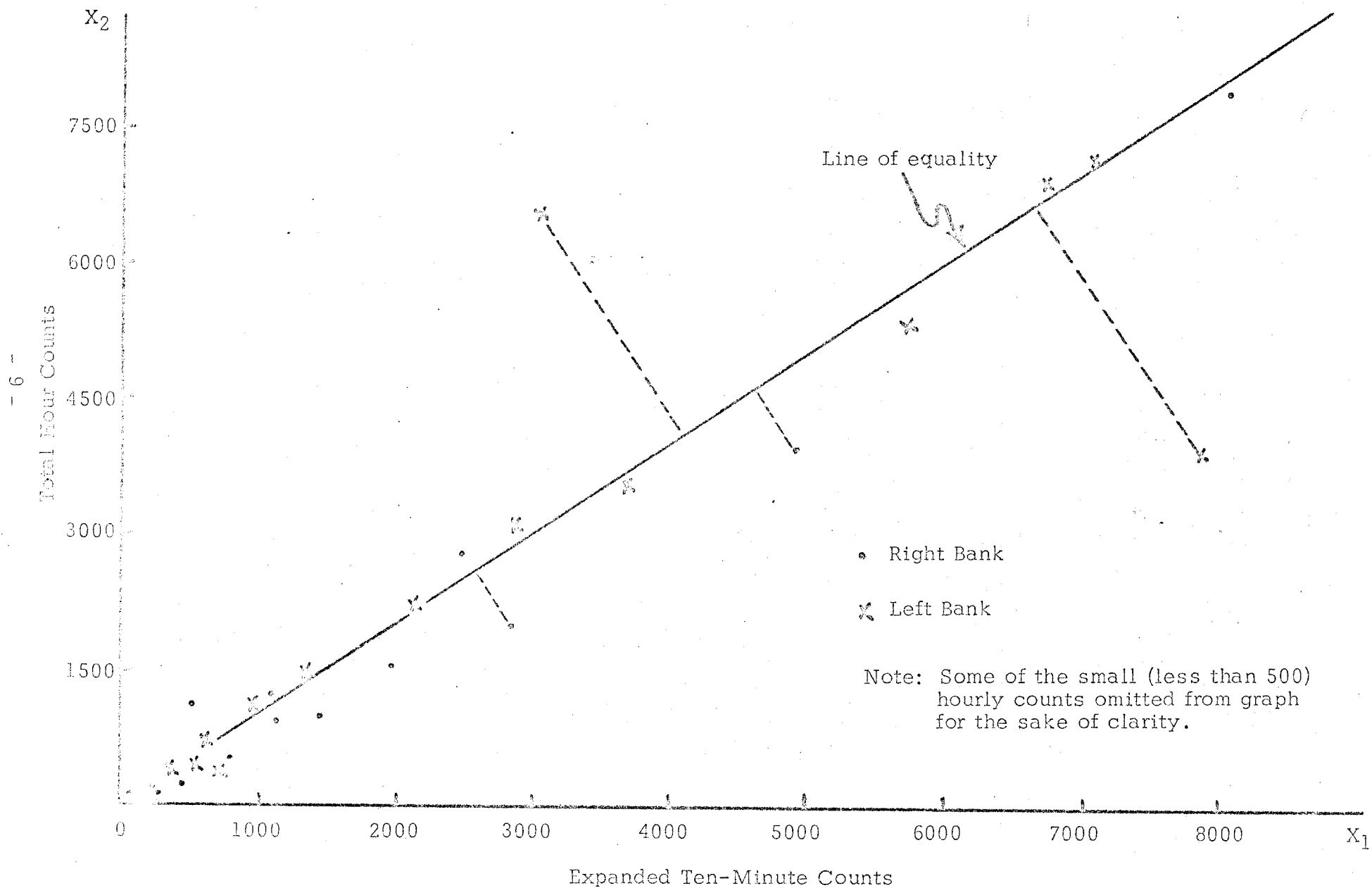
^{4/} Total sample count \div sample size.

^{5/} Relative Error = $100 \times [\Sigma (\text{Hourly Estimates}) - \Sigma (\text{Hourly Counts})] \div \Sigma (\text{Hourly Counts})$

^{6/} Separation by species was not possible. Pinks, chums and sockeyes counted.

^{7/} Based on preliminary estimate of season migration.

Figure 4. 1965 Egegik River Tower Counts, Sockeye Salmon
Total Hour Counts Versus Expanded Ten-Minute Counts



If one is allowed the freedom of accepting the assumption of a bivariate normal population, the values of r , used as estimates of the population correlation coefficients, indicate significant (i.e., 95% level) correlation between the hourly estimates and hourly counts for all rivers.

Although the above correlation between the hourly counts and hourly estimates is of interest in that it does indicate good correlation between these two variables, as mentioned above, the primary concern is with the agreement between the sum of the hourly estimates and the hourly counts over the season. The relative errors occurring in the individual hourly estimates (relative to the hourly counts) may be statistically significant in some cases; however, if these relative errors occur without bias, then the sum of the hourly estimates will provide an unbiased estimate of the sum of the hourly counts. To express this more concisely, if we have

$$Y_i = X_i + \epsilon_i$$

where

$$\begin{aligned} Y_i &= \text{the hourly counts, i.e. the hourly migration,} \\ X_i &= \text{the hourly estimates, and} \\ \epsilon_i &= \text{the error with which } Y_i \text{ is estimated by } X_i, \end{aligned}$$

and if ϵ_i is randomly distributed with mean zero, then if we sum Eq. (1) over all possible counts,

$$\sum Y_i = \sum X_i + \sum \epsilon_i$$

$$\text{i.e., } \sum Y_i = \sum X_i$$

since $\sum \epsilon_i = 0$ i.e., the seasonal sum of the hourly estimates will provide an unbiased estimate of the seasonal sum of the hourly counts.

To investigate whether $\bar{\epsilon} = 0$, the relative error was calculated for each set of data. The results are shown in Table 1.

The relative error between the total hourly estimates and the total hourly counts varied in absolute value from 0.6% (Nuyakuk R., sockeye, 1966) to 34.9% (Igushik R., 1965) with a geometric mean of 5.1%. However, two comments should be made regarding these relative errors:

- 1) The relative errors are equally divided between positive (over-estimates) and negative (under-estimate) errors with seven over-estimates and seven under-estimates. Furthermore, the arithmetic mean (used so the algebraic signs of the error could be included) is +0.9%. This value is not statistically different (at the 95% level) from zero.

This indicates that no directional error (i.e., bias) is occurring in the sum of the hourly estimates.

- 2) It should be noted that, in eleven of the fourteen samples, less than one-fourth of the total seasonal migration for any one river was counted during the sampling period. Moreover, the average sample size of 31.7 (hours) is less than the number of hours contained in 1.5 days, whereas the total migrations are generally enumerated during a period of not less than 30 days. Thus, a seasonal migration estimate would generally consist of the sum of approximately 700 individual hour estimates, or more than twenty times the number of hours contained in the average sampling period for this study. If, in fact, the error of estimate (between the hourly counts and hourly estimates) is unbiased as indicated, the error between the sum of the hourly counts and the hourly estimates would be expected to be less when the sum is taken over the entire season than when the sum is just over the sampling periods.

At this point it may be instructive to concentrate our attention on the data collected from the Igushik River (1965) and the Togiak River (1966) as these samples reflected the largest relative errors, viz. - 34.9% and +21.8% respectively. In both cases, sockeye salmon were being counted. The following points are of interest:

- 1) Of the fourteen samples, the Igushik and Togiak samples represented the smallest and third smallest sample sizes respectively. In the Igushik sample, 2 hours accounted for 81% of the variation, while in the Togiak sample 3 hours accounted for 70% of the variation.
- 2) The Igushik and Togiak samples represent the second and third smallest percentages of the total season migrations counted during the sampling periods.
- 3) If we express the variations of the hourly counts within a sample as the coefficient of variation (i.e., the ratio of the standard deviation to the mean), the Igushik and Togiak samples represent respectively the fifth and fourth largest coefficients of variation recorded.

It appeared, therefore, that the relative error between the sum of sample hourly estimates and hourly counts depended on the sample size (which directly represents a measure of the percentage of the total seasonal migration counted during the sampling period) and the variation of the hourly counts within a sample. To investigate this, the relative error was plotted against the sample size (Figure 5) and the coefficient of variation (Figure 6).

Figure 5. Relationship between relative error in total hourly estimates and sample size.

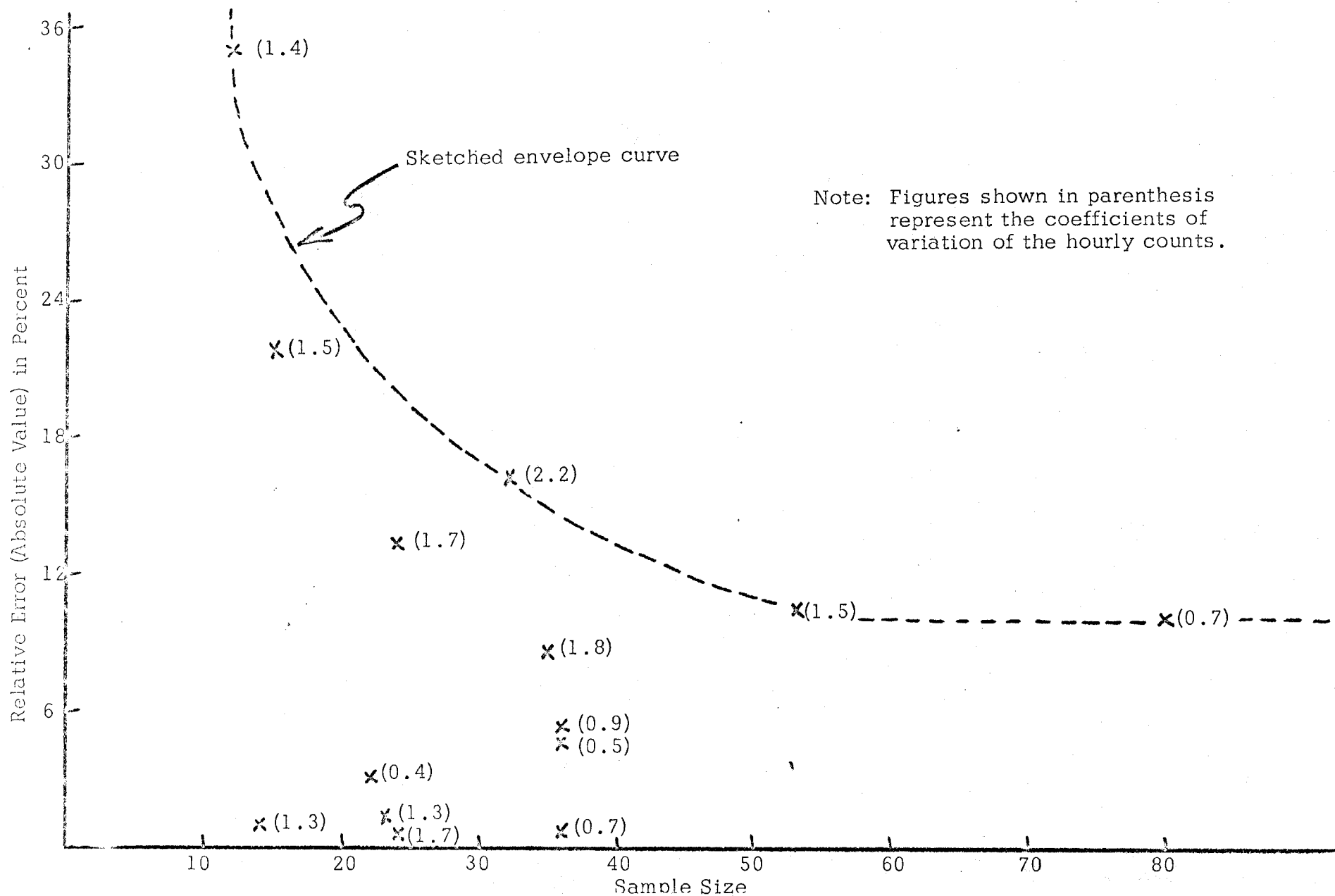
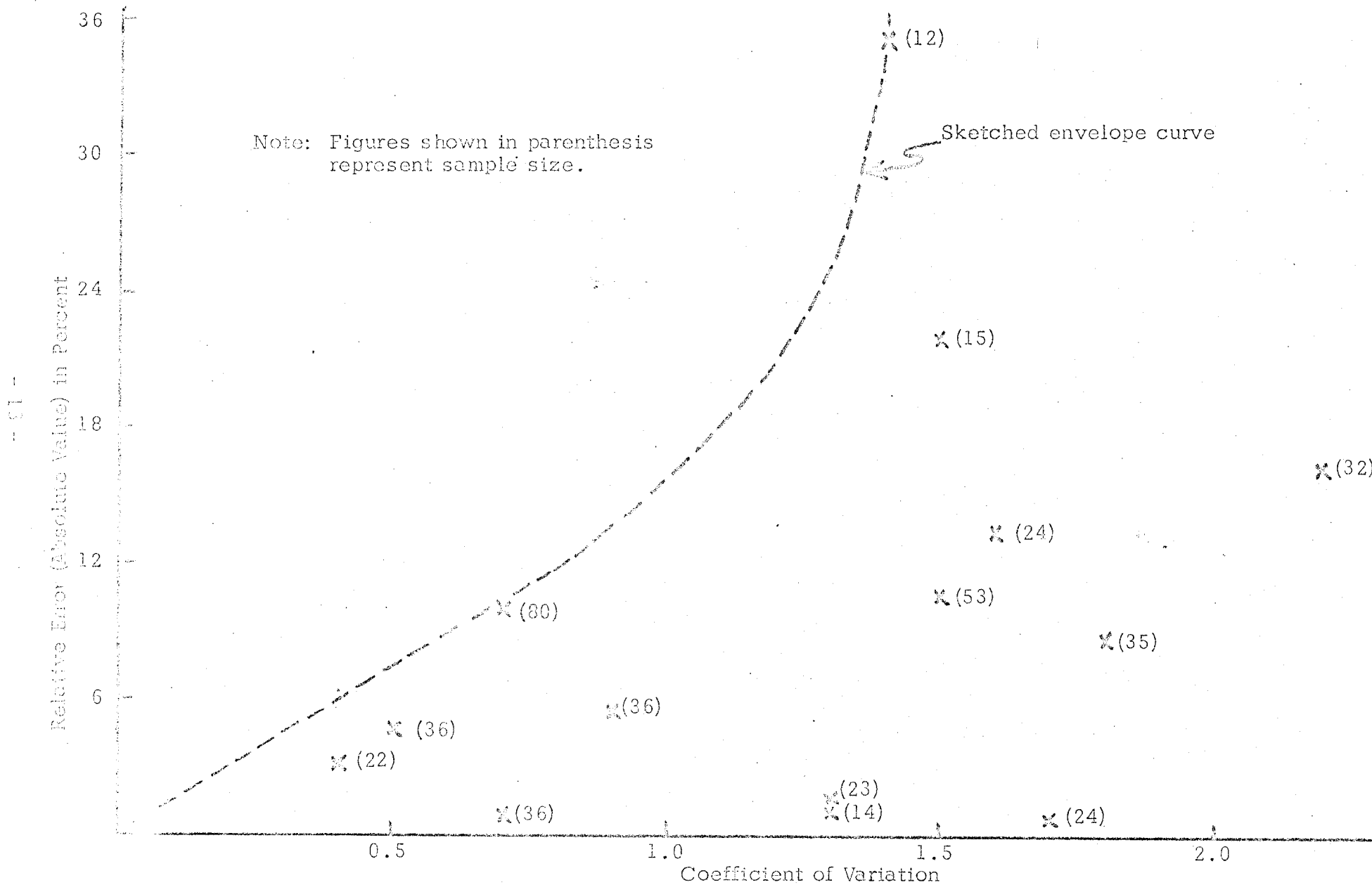


Figure 6. Relationship between relative error in total hourly estimates and the coefficient of variation of the hourly counts.



The important point to observe in Figures 5 and 6 is that the variation in the relative error decreases as the sample size increases and the coefficient of variation decreases. Although this is not equivalent to saying that a small sample size and/or a large coefficient of variation will result in a large relative error, it does imply that the chances of a large relative error occurring are greater under these conditions. In practical terms, this means that escapement estimates for short-term periods (i.e. less than several days) may be expected to exhibit significant relative errors in some cases. The chances of a significant relative error are also increased if the migration is very erratic, i.e., if the coefficient of variation is large. Conversely, however, the relative error can be expected to be small over long-term (e.g. one month) periods, especially if the migration is not excessively erratic.

A situation which could result in a significant relative error even though escapement estimates were for a period of approximately one month would be one similar to that occurring on the Ugashik River in 1963. During the 1963 season, 47% of the seasonal escapement passed the Ugashik counting tower in one day, i.e., on July 15, 181,000 sockeye were estimated to have passed the tower, while the final season total was 388,000. The next largest day's escapement was 43,000 on July 18. A large relative error occurring in the estimate for July 15 may not be cancelled by the errors occurring in the smaller estimated escapements for the other days. (However, it should be noted that a 30% relative error for the July 15 estimate would represent only a 14% relative error for the season). The Ugashik system is rather unique relative to the other Bristol Bay rivers which do not exhibit such a high degree of concentration in the escapement patterns. Furthermore, the escapement patterns for the Ugashik system generally do not exhibit the extreme degree of concentration existing in the 1963 migration.

For the purpose of analyzing the relationship between the relative error, the sample size and the coefficient of variation, multiple regression analysis was applied to the data. It was assumed that the relative error was directly proportional to the coefficient of variation and inversely proportional to the square root of the sample size. The following relationship was obtained:

$$Y = -6.90 + 7.024 X_1 + 2.064 X_2 \quad (1)$$

where

$$X_1 = 10 \times \text{the inverse square root of the sample size}$$

$$X_2 = \text{the coefficient of variation, and}$$

$$Y = \text{the relative error}$$

However, the sum of squared deviations $\Sigma(Y - \hat{Y})^2$ from Eq. (1) was only 16% less than the sum of squared deviations from the mean, indicating that

the sample size and coefficient of variation alone do not explain the variations in the relative errors.

Again, if we are allowed the freedom of assuming random sampling from a tri-variate normal distribution, the partial correlation coefficients $r_{X_1Y \cdot X_2} = 0.344$ (d.f. = 11) and $r_{X_2Y \cdot X_1} = 0.159$ (d.f. = 11) do not represent significant correlation between the relative error and the inverse square root of the sample size (with the coefficient of variation considered constant) or between the relative error and the coefficient of variation (with the sample size considered constant).

The data shown graphically in Figures 5 and 6 and the results above indicate that sufficient conditions for small, i.e., acceptable, relative errors are a large sample size (i.e., hourly estimates for period of approximately one week or more) and non-excessive variations in the hourly escapements. Although a small sample size and/or large coefficient of variation increase the chances of a large relative error, these conditions do not necessarily imply a large relative error.

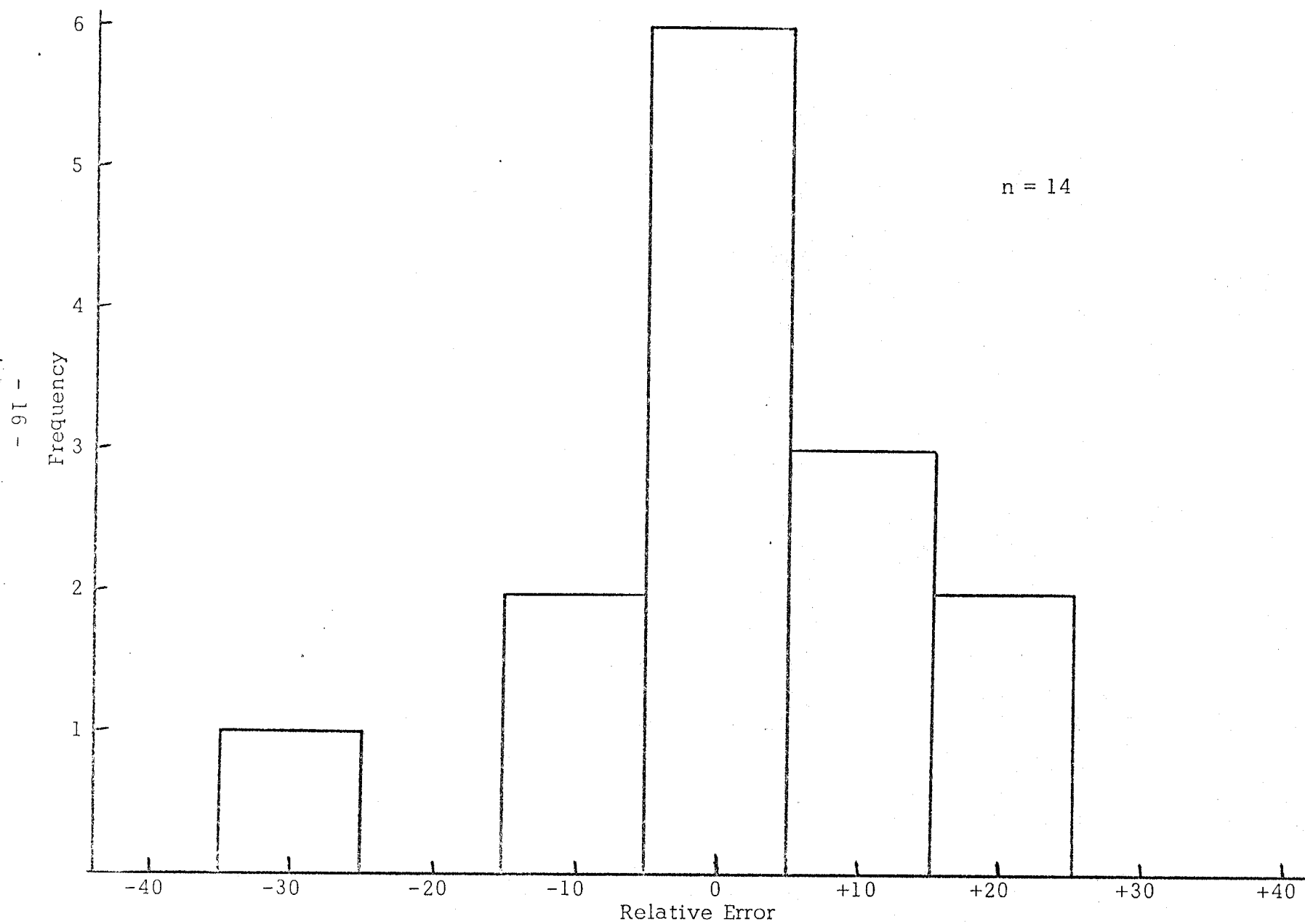
Since the sample size (i.e., number of hours) and coefficient of variation for a given season cannot be controlled, the next logical step to increase the accuracy of the hourly estimates would be to increase the time counted each hour. The following table illustrates the effect of increasing to 20 minutes the time counted each hour. For this purpose, only those systems with the four largest (in magnitude) relative errors are considered.

<u>SYSTEM</u>	<u>RELATIVE ERROR</u>	
	<u>10-MINUTE COUNTS</u>	<u>20-MINUTE COUNTS</u>
Igushik River, 1965	-34.9%	-6.6%
Egegik River, 1965, Left Bank	+13.4	+9.8
Togiak River, 1966	+21.8	+9.9
Nuyakuk River, 1966, Pink Salmon	+16.3	+5.2

In each case, counting for twenty minutes of each hour reduced the relative error to less than 10%. This suggests that in the event that extreme variations occur in the hourly counts during the season, if a high degree of concentration occurs in the migration pattern, if the migration occurs in a very short period or if short period estimates are desired for the purpose of comparison with aerial surveys, counting time per hour should possibly be increased to 20 minutes. In this manner the relative error would very likely remain under 10%.

As a final method of determining what range of relative errors one might expect if sampling is conducted in the same manner as in this report, we calculate the confidence interval associated with the mean of the relative errors given in Table 1. As seen from Figure 7, the distribution of

Figure 7. Frequency Distribution of Relative Errors, Counting Tower Data, 1965-66.



this relative error is approximately normal. The confidence interval for the mean is given (Cochran, 1963) by

$$\bar{X} - t_{1-\alpha/2, n-1} s/\sqrt{n} \leq \mu \leq \bar{X} + t_{1-\alpha/2, n-1} s/\sqrt{n}$$

where \bar{X} = mean relative error,

μ = true mean

t = Student's "t" statistic

s = sample estimate of the standard deviation

n = sample size.

For $\alpha = .05$, $n = 14$ we have $t_{1-\alpha/2, n-1} = 2.160$.

Thus, we have

$$0.9 - (2.16) (3.69) \leq \mu \leq 0.9 + (2.16) (3.69)$$

$$\text{i.e.,} \quad -7.1 \leq \mu \leq 8.9$$

Therefore, the 95% confidence (or, more correctly, fiducial) interval for the mean relative error is (-7.1%, + 8.9%); i.e., if sampling is conducted in the same manner as described in this report, then in 95 times out of a 100 the true mean (relative error) will be contained in the interval (-7.1%, + 8.9%).

IV. CONCLUDING REMARKS AND RECOMMENDATIONS

In conclusion, the data in this report indicates that, in general, relative errors of less than 10% occur in the seasonal estimates of the number of migrating salmon as a result of using 10-minute counts made from counting towers to estimate hourly migration. It should not be implied that each hourly estimate (based on a 10-minute count) enjoys the same degree of accuracy (relative to the true hourly migration) as does the seasonal sum of hourly estimates (relative to the seasonal migration). However, the fact that the errors in the hourly estimates occur without bias results in a cancelling of these errors in the total seasonal estimate of the migration.

Some situations may occur in which counting time per hour should be increased to 20 minutes to insure acceptable levels of accuracy. Some examples where 20-minute counts per hour may be desirable are:

- a) If short period escapement estimates (obtained from counting towers) were to be compared with aerial survey estimates, hourly 20-minute counts would more exactly estimate salmon migrating during the period in question.

- b) If counting is to be discontinued during certain portion of the day to free the personnel for other duties, 20-minute hourly counts made for the remaining portion of the day could be used to estimate the total daily migration.
- c) If a highly concentrated migration pattern is anticipated, 20-minute hourly counts could be made for the period of peak migration to increase the probability of obtaining seasonal migration estimates containing less than 10% relative error.

V. ACKNOWLEDGEMENTS

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The above biologists also reviewed the original manuscript and made numerous pertinent suggestions.

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VII. APPENDIX

Tables A-1 through A-12: Basic Counting Tower Data

Table B-1 : Analysis of Variance Tables

Table A-1. 1965 Kwiniuk River Counting Tower Data, Chum Salmon (n = 53)

<u>Expanded Ten- Minute Counts</u>	<u>Total Hour Counts</u>	<u>Expanded Ten- Minute Counts</u>	<u>Total Hour Counts</u>
0	6	42	44
96	168	1,368	645
0	34	72	52
0	1	210	87
0	2	0	4
0	43	48	27
426	129	132	92
0	23	0	4
0	182	66	66
12	92	162	189
408	917	432	362
72	23	60	101
0	20	198	330
780	566	60	17
18	17	48	40
150	116	0	5
0	74	0	10
144	111		
222	96	Totals	6,972
6	70		6,302
0	60		
0	6		
96	68		
36	22		
0	16		
0	5		
0	1		
54	156		
24	4		
60	90		
24	11		
0	142		
474	261		
12	15		
768	460		
192	220		

Table A-2. 1965 Kwiniuk River Counting Tower Data, Pink Salmon (n = 35)

<u>Expanded Ten- Minute Counts</u>	<u>Total Hour Counts</u>
120	30
0	3
0	4
66	16
0	1
0	12
0	2
0	3
0	6
0	2
0	19
0	11
0	2
0	14
0	6
12	6
0	2
0	3
30	37
30	15
60	58
6	3
0	13
90	112
240	201
0	1
240	235
84	71
0	1
78	63
228	245
24	7
48	39
0	4
0	2
Totals 1,356	1,249

Table A-3. 1965 Igushik River Counting Tower Data, Sockeye Salmon (n = 12)

<u>Expanded Ten- Minute Counts</u>	<u>Expanded Twenty- Minute Counts -</u>	<u>Total Hour Counts</u>
0	0	16
0	0	107
36	72	138
24	12	104
312	255	196
60	534	591
0	0	9
0	0	1
234	120	115
144	141	103
24	351	256
<u>924</u>	<u>1,038</u>	<u>1,064</u>
Totals 1,758	2,523	2,700

Table A-4. 1965 Kvichak River Counting Tower Data, Sockeye Salmon
(Counts in thousands of fish)

Left Bank (n = 36)		Right Bank (n = 22)	
Expanded Ten- Minute Counts	Total Hour Counts	Expanded Ten- Minute Counts	Total Hour Counts
2.46	3.91	18.48	16.23
3.75	4.40	10.77	10.34
3.66	4.00	11.94	11.01
11.16	10.83	12.36	15.17
10.77	10.34	11.76	13.08
13.50	14.07	16.14	12.20
19.26	15.83	11.10	19.86
6.18	8.23	40.44	26.74
5.94	4.53	19.20	19.16
6.00	4.15	32.64	42.92
6.36	6.97	19.44	20.50
16.02	16.69	28.92	30.20
15.90	16.73	15.00	14.74
16.20	15.86	13.68	15.70
18.60	19.17	7.98	10.15
22.68	24.41	11.70	10.58
18.42	27.18	16.92	17.71
21.00	23.09	22.32	22.95
18.42	21.07	11.04	12.58
20.58	21.07	12.66	12.37
17.82	18.73	12.18	11.84
21.54	20.81	19.20	21.92
21.06	19.34		
20.04	19.96	Totals	375.87
22.38	22.40		
21.42	24.26		
17.22	16.23		
17.22	19.93		
20.64	20.73		
18.18	20.68		
17.82	19.81		
19.98	19.78		
17.40	17.20		
16.56	18.58		
14.70	16.45		
17.34	18.28		
Totals	558.18		585.70

Table A-5. 1965 Egegik River Counting Tower Data, Sockeye Salmon

Left Bank (n = 24)		Right Bank (n = 23)	
Expanded Ten- Minute Counts	Total Hour Counts	Expanded Ten- Minute Counts	Total Hour Counts
72	54	2,862	3,096
702	313	5,778	5,343
0	2	3,690	3,579
0	57	2,124	2,158
4,926	3,903	7,062	7,127
792	551	7,854	3,918
510	1,178	12	2
8,058	7,930	6	1
408	266	588	432
1,086	1,220	0	1
1,122	920	12	107
1,992	1,521	6,744	6,904
0	6	3,036	6,545
2,466	2,792	12	9
2,838	2,027	0	22
198	196	600	699
1,416	967	1,368	1,478
78	140	996	1,102
120	21	708	349
0	2	372	375
264	64	0	10
720	423	0	21
96	93	0	3
282	174		
Totals 28,146	24,820	43,824	43,281

Table A-6. 1965 Coghill River Counting Tower Data, Mixed Species (n = 80)

<u>Expanded Ten- Minute Counts</u>	<u>Total Hour Counts</u>	<u>Expanded Ten- Minute Counts</u>	<u>Total Hour Counts</u>
42	220	264	339
276	230	102	271
180	121	198	147
402	192	108	112
96	88	48	62
42	297	54	73
436	518	102	180
192	253	354	329
252	227	420	281
198	357	384	236
306	179	264	163
132	187	18	65
12	94	42	50
186	94	12	62
6	103	48	60
90	119	90	183
102	83	150	241
96	113	252	291
54	52	156	131
36	40	186	253
360	173	174	192
54	98	270	326
90	53	66	111
18	46	198	492
66	44	204	173
30	201	198	189
624	539	180	260
444	482	426	220
354	422	330	373
120	99	222	380
186	161	306	282
24	47	66	137
84	47	48	28
0	103	126	103
210	154	48	39
96	92	408	314
6	47	96	166
6	45	120	100
174	172	252	226
336	367	60	275
Totals		13,468	15,174

Table A-7. 1966 Kwiniuk River Counting Tower Data, Chum Salmon^{1/} (n = 36)

<u>Expanded Ten- Minute Counts</u>	<u>Total Hour Counts</u>
0	57
0	77
0	99
150	86
0	118
276	71
0	52
18	90
0	81
0	250
0	74
240	210
48	56
420	76
0	81
102	153
132	245
822	811
1,080	723
180	552
606	420
372	290
504	243
240	245
264	161
126	112
264	96
0	279
306	239
42	175
18	172
258	224
102	83
0	80
336	135
0	379
Totals 6,906	7,295

^{1/} Due to the large number of hourly counts obtained, the first 36 non-negative hourly counts greater than 50 were chosen for analysis.

Table A-8. 1966 Kwiniuk River Counting Tower Data, Pink Salmon ^{1/} (n = 36)

<u>Expanded Ten- Minute Counts</u>	<u>Total Hour Counts</u>
66	55
0	117
306	96
168	121
54	107
108	139
120	131
138	120
60	78
282	90
120	67
0	58
414	374
408	428
240	200
0	153
0	59
108	74
78	62
144	115
168	158
102	166
108	74
102	294
174	228
600	457
132	135
60	62
0	128
54	110
216	198
54	161
60	61
48	80
324	186
156	71
Totals 5,172	5,213

^{1/} Due to the large number of hourly counts obtained, the first 36 hourly counts greater than 50 were chosen for analysis.

Table A-9. 1966 Togiak Counting Tower Data, Sockeye Salmon (n = 15)

<u>Expanded Ten- Minute Counts</u>	<u>Expanded Twenty- Minute Counts</u>	<u>Total Hour Counts</u>
360	321	319
360	339	375
120	81	48
162	117	103
72	57	44
0	0	1
60	81	54
54	42	23
174	147	130
0	18	15
0	0	1
0	39	26
0	12	13
72	39	21
12	12	14
Totals 1,446	1,305	1,187

Table A-10. 1966 Nuyakuk River Counting Tower Data, Sockeye Salmon (n = 24)

<u>Expanded Ten- Minute Counts</u>	<u>Total Hour Counts</u>
1,650	2,727
4,794	5,147
534	298
0	32
2,166	1,773
1,176	1,030
174	354
426	387
1,944	1,437
2,226	1,102
402	471
252	786
108	98
168	71
48	85
90	62
102	158
150	203
30	56
6	15
6	38
48	27
54	53
42	84
Totals 16,596	16,494

Table A-11. 1966 Nuyakuk River Counting Tower Data, Pink Salmon (n = 32)

<u>Expanded Ten- Minute Counts</u>	<u>Total Hour Counts</u>
18	20
24	22
0	2
0	0
42	21
0	0
0	0
0	4
12	11
6	8
6	2
0	4
90	112
126	94
36	33
18	23
324	243
84	223
348	129
18	24
30	78
90	62
36	83
60	107
1,710	1,572
1,962	1,639
3,114	3,043
4,812	3,518
252	195
12	137
576	711
<u>576</u>	<u>241</u>
Totals 14,382	12,361

Table A-12. 1966 Nushagak River Counting Tower Data, Pink Salmon (n = 14)

<u>Expanded Ten- Minute Counts</u>	<u>Total Hour Counts</u>
72	196
2,910	2,289
0	15
954	956
486	775
6	432
66	872
7,026	6,584
792	971
6,570	9,060
12	203
10,752	8,124
1,608	1,144
<u>2,412</u>	<u>2,407</u>
Totals 33,666	34,028

Table B-1. Analysis of variance for regression of total hour counts on expanded ten-minute counts.

Kwiniuk River, 1965, Chums			Kwiniuk River, 1965, Pinks		
<u>Source of Variation</u>	<u>Degrees of Freedom</u>	<u>Sum of Squares</u>	<u>Source of Variation</u>	<u>Degrees of Freedom</u>	<u>Sum of Squares</u>
Due to Regression	1	1,051,042	Due to Regression	1	81,367
Deviations from Regression	51	617,279	Deviations from Regression	33	60,141
Total	52	1,668,321	Total	34	141,508
Igushik River, 1965, Sockeye					
<u>Source of Variation</u>	<u>Degrees of Freedom</u>	<u>Sum of Squares</u>			
Due to Regression	1	705,278			
Deviations from Regression	10	338,032			
Total	11	1,043,310			
Kvichak River, 1965, Sockeye, Left Bank			Kvichak River, 1965, Sockeye, Right Bank		
<u>Source of Variation</u>	<u>Degrees of Freedom</u>	<u>Sum of Squares</u>	<u>Source of Variation</u>	<u>Degrees of Freedom</u>	<u>Sum of Squares</u>
Due to Regression	1	1,286,810	Due to Regression	1	920,818
Deviations from Regression	34	188,890	Deviations from Regression	20	381,612
Total	35	1,475,700	Total	21	1,302,430

Table B-1 (Continued)

Egegik River, 1965, Sockeye, Left Bank			Egegik River, 1965, Sockeye, Right Bank		
<u>Source of Variation</u>	<u>Degrees of Freedom</u>	<u>Sum of Squares</u>	<u>Source of Variation</u>	<u>Degrees of Freedom</u>	<u>Sum of Squares</u>
Due to Regression	1	69,777,545	Due to Regression	1	109,471,370
Deviations from Regression	22	2,306,696	Deviations from Regression	21	25,678,470
Total	23	72,084,241	Total	22	135,149,840
Coghill River, 1965, Mixed Species					
<u>Source of Variation</u>	<u>Degrees of Freedom</u>	<u>Sum of Squares</u>			
Due to Regression	1	717,250			
Deviations from Regression	78	568,144			
Total	79	1,285,394			
Kwiniuk River, 1966, Chum			Kwiniuk River, 1966, Pink		
<u>Source of Variation</u>	<u>Degrees of Freedom</u>	<u>Sum of Squares</u>	<u>Source of Variation</u>	<u>Degrees of Freedom</u>	<u>Sum of Squares</u>
Due to Regression	1	523,553	Due to Regression	1	203,127
Deviation from Regression	34	604,795	Deviation from Regression	34	150,137
Total	35	1,128,348	Total	35	353,264

Table B-1 (Continued)

Togiak River, 1966, Sockeye					
<u>Source of Variation</u>	<u>Degrees of Freedom</u>	<u>Sum of Squares</u>			
Due to Regression	1	173,309			
Deviations from Regression	13	12,048			
Total	14	185,357			
Nuyakuk River, 1966, Sockeye			Nuyakuk River, 1966, Pink		
<u>Source of Variation</u>	<u>Degrees of Freedom</u>	<u>Sum of Squares</u>	<u>Source of Variation</u>	<u>Degrees of Freedom</u>	<u>Sum of Squares</u>
Due to Regression	1	28,029,729	Due to Regression	1	22,201,972
Deviations from Regression	22	3,358,545	Deviations from Regression	30	616,088
Total	23	31,388,274	Total	31	22,818,060
Nushagak River, 1966, Pinks					
<u>Source of Variation</u>	<u>Degrees of Freedom</u>	<u>Sum of Squares</u>			
Due to Regression	1	111,721,990			
Deviations from Regression	12	12,828,724			
Total	13	124,550,714			

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